Environmental Radiation Monitoring

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Introduction

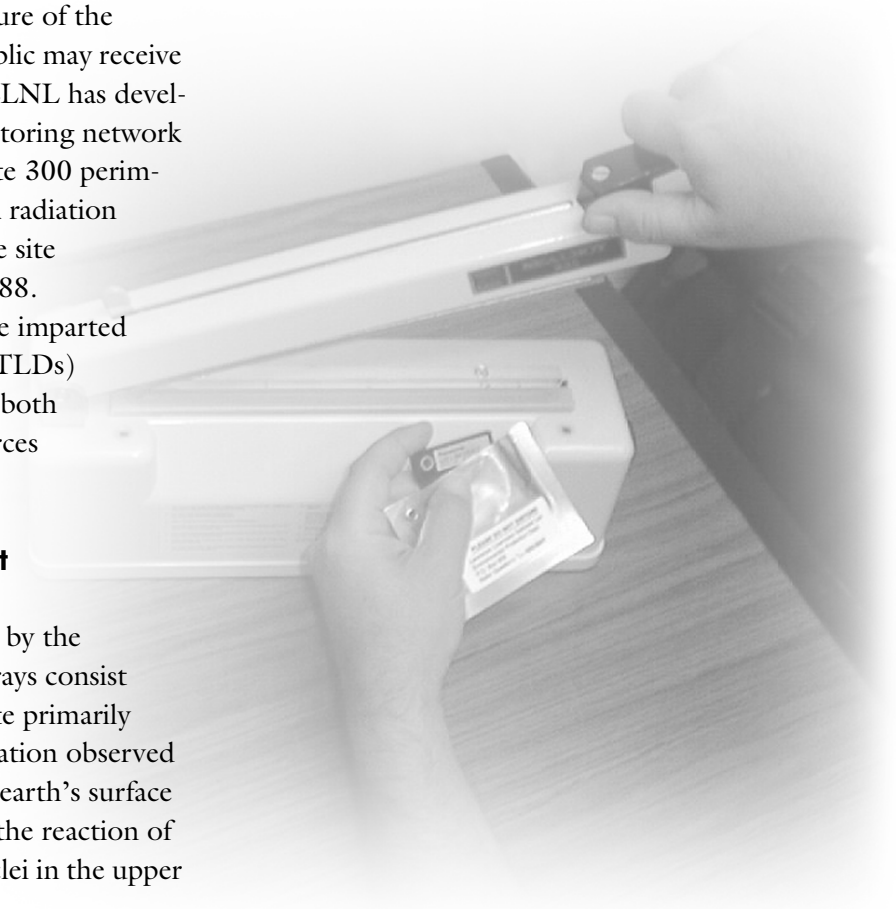
In accordance with federal regulations and applicable portions of Department of Energy (DOE) Orders 5400.1 and 5400.5, Lawrence Livermore National Laboratory monitors gamma radiation to establish radiation levels in its vicinity and to determine the direct environmental radiological impact of its operations. Gamma radiation in the environment primarily occurs naturally from terrestrial and cosmic sources. Because environmental radiological monitoring is used as one measure of the potential radiation dose that the public may receive as the result of LLNL operations, LLNL has developed an extensive radiological monitoring network for the Livermore site perimeter, Site 300 perimeter, and off-site locations. Gamma radiation has been measured at the Livermore site since 1973 and at Site 300 since 1988. The absorbed gamma radiation dose imparted to thermoluminescent dosimeters (TLDs) is the result of TLD exposure from both terrestrial and cosmic radiation sources as well as LLNL sources, if any.

Cosmic Radiation Component

Gamma radiation in air is produced by the interaction of cosmic rays. Cosmic rays consist of high-energy particles and emanate primarily from beyond the solar system. Radiation observed in the lower atmosphere and at the earth's surface are secondary radiations formed in the reaction of these high-energy particles with nuclei in the upper atmosphere. The cosmic radiation component accounts for about half the observed site annual average gamma radiation.

Terrestrial Radiation Component

Terrestrial gamma radiation is caused by naturally occurring isotopes of the uranium (uranium-238 parent), thorium (thorium-232 parent), and actinium (uranium-235 parent) decay series that are present in soil worldwide and that produce



gamma radiation during radioactive decay. The concentration of naturally occurring radionuclides in soil is variable and is determined by the ratio of thorium-232 to uranium-238 (present in these regions at the time of the earth's formation over four billion years ago), which ranges from 3 to 4 around the world. By characterizing the natural background radiation, LLNL can determine whether or not there is a contribution to gamma exposure from Laboratory operations.

General Methods

LLNL deploys TLDs in the field to assess the environmental impact of laboratory operations at both the Livermore site and Site 300. This assessment is done by comparing the gamma radiation data acquired from the Livermore perimeter site locations to various locations monitored in the Livermore Valley, and gamma-radiation data from Site 300 perimeter locations to locations in the City of Tracy and near Site 300.

As previously mentioned, the variability of the naturally occurring radioisotopes present in the soil due to geological formations is the largest contributor to variations in measurements. Meteorological conditions contribute to seasonal variability, as does cosmic variation.

LLNL deploys TLDs at the beginning of each quarter of the year and retrieves them from the monitoring locations as near to the end of the quarter as possible in order to have a 90-day exposure period. All data are normalized to a 90-day standard quarter basis in order to make valid comparisons for the measurement period.

Details of the TLD calculations are described in an Operations and Regulatory Affairs Division (ORAD) procedure. Reporting of external gamma radiation dose may be found in the Data Supplement.

Monitoring Locations

In 2000, external doses from gamma radiation were monitored at 14 Livermore site perimeter locations (shown in **Figure 12-1**) and at 23 Livermore Valley locations (**Figure 12-2**), which are used for background comparison to perimeter location data. Similarly, gamma doses are monitored at eight perimeter monitoring locations at Site 300 (**Figure 12-3**). Additionally, five off-site locations near Site 300 and two locations in nearby Tracy are also monitored for comparison to the Site 300 data. Summary dose calculations for all gamma-monitoring locations are presented in **Table 12-1**.

Collocated Monitoring Locations

The State of California Department of Health Services, Radiological Health Branch (CDHS-RHB) performs routine, independent gamma monitoring at several sites collocated with LLNL's TLD network. CDHS-RHB site locations correspond to several Livermore site perimeter, valley, Site 300, and off-site locations near Site 300.

Locations at Site 300

During the second quarter collection/third quarter deployment, all second quarter samples with the exception of 86 and 121 were damaged due to an accident involving a vehicle fire enroute. For the safety of the personnel involved in future deployments, east and north perimeter sites were eliminated in the third quarter and additional locations were supplemented, following an examination of the incident safety measures taken in an attempt to prevent future occurrences of this nature. The original locations initially removed were reinstated in the fourth quarter in order to preserve historical data.

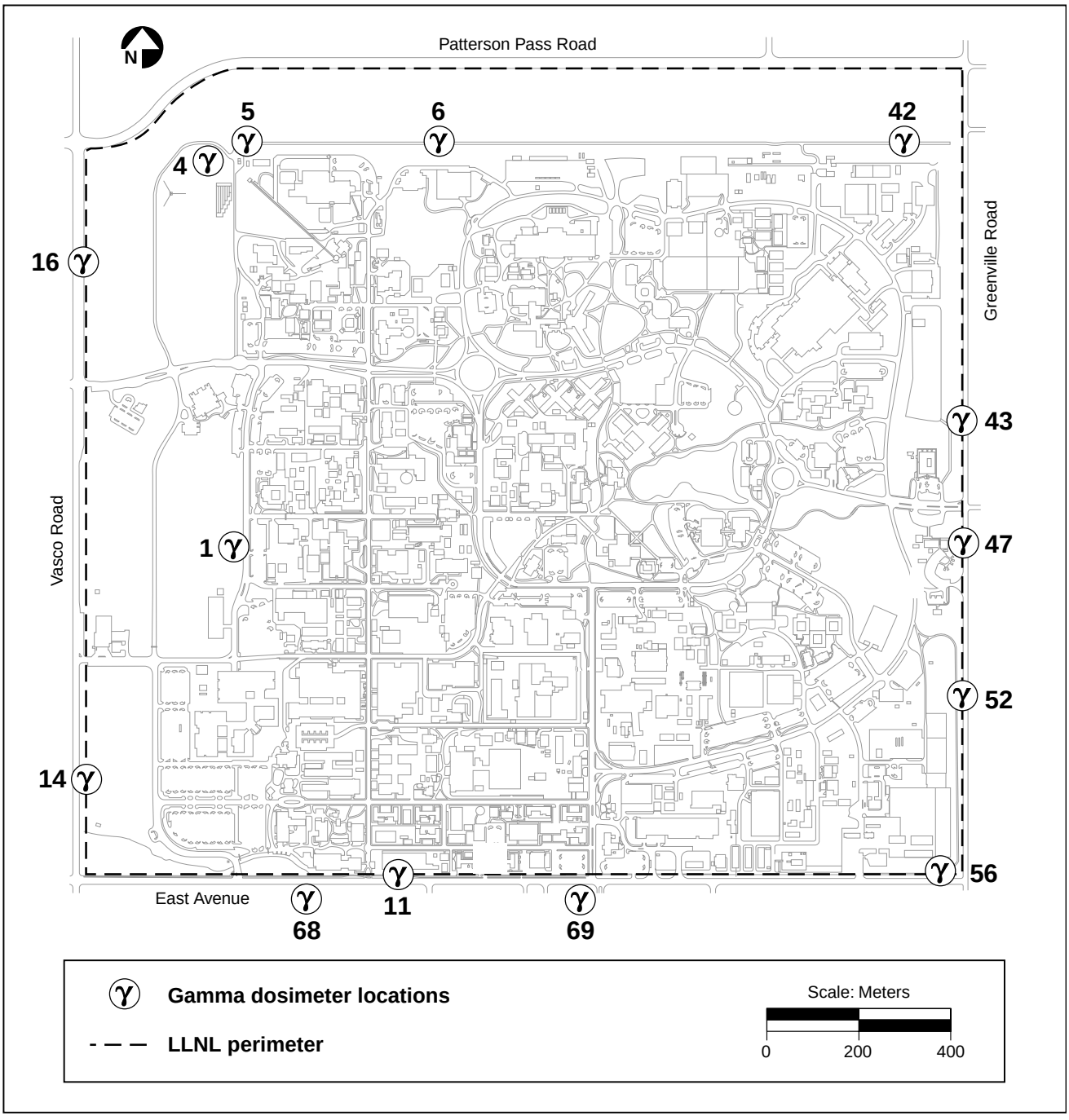


Figure 12-1. Gamma dosimeter locations, Livermore site, 2000

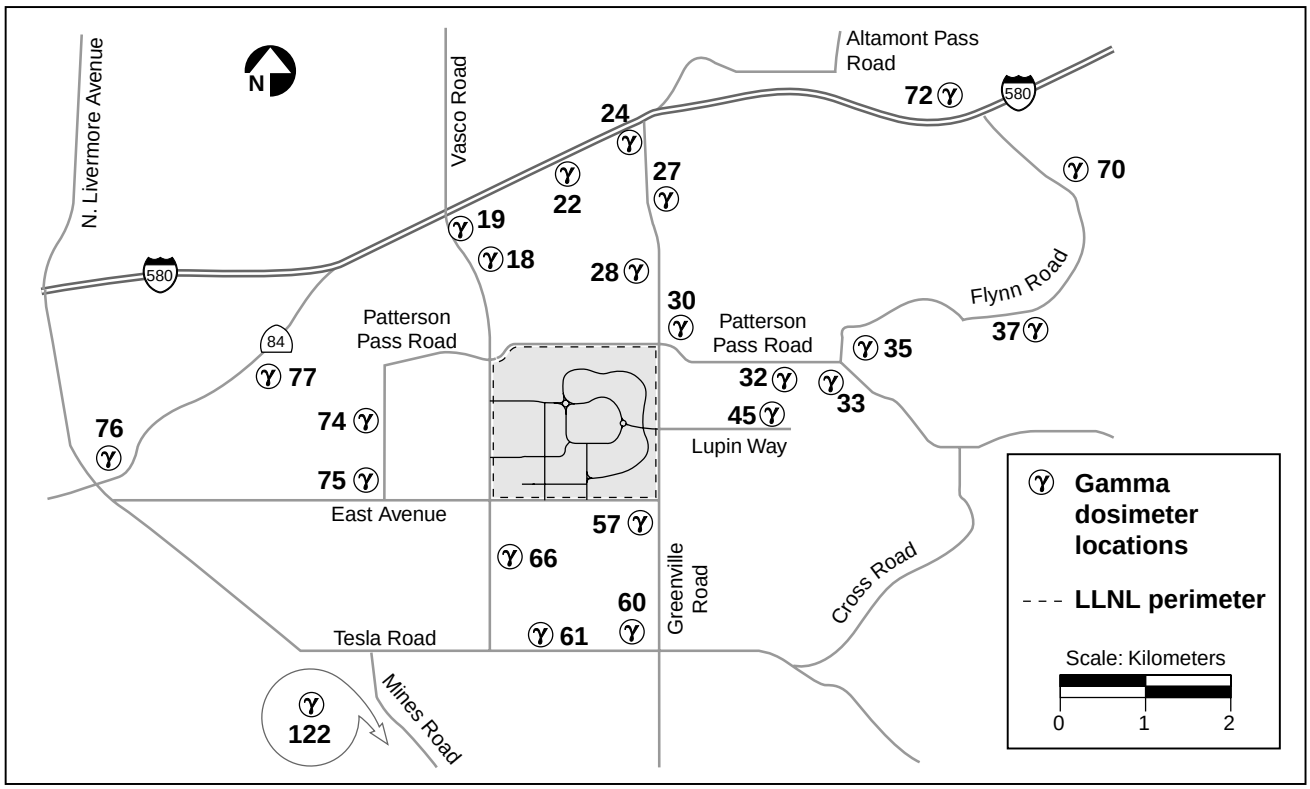


Figure 12-2. Gamma dosimeter locations, Livermore Valley, 2000

Results of Gamma Monitoring

Figure 12-4 shows gamma doses for the Livermore site perimeter, Livermore Valley, and Site 300 from 1988 through 2000. Beginning in 1995, all quarterly gamma radiation data points were normalized to standard, 90-day quarters, as is the practice of the Nuclear Regulatory Commission (NRC) (Struckmeyer 1994). Correcting the data to standard quarters to normalize the data to the same number of days deployed reduces the variability caused by exposure duration.

Livermore Site

Table 12-1 presents a summary of the quarterly and annual TLD gamma radiation dose equivalents for the Livermore site perimeter locations and Livermore Valley off-site locations. The annual 2000 dose equivalent from external, direct-radiation exposure at the Livermore site perimeter, 0.571 mSv, is statistically the same as the background external dose measured in the Livermore Valley, 0.565 mSv. Table 12-2 lists the yearly doses due to direct gamma radiation at the Livermore site perimeter. All doses fall within the predicted range for background radiation, and no LLNL operational impacts are discernible.

Site 300

As seen in Table 12-1, the measured Site 300-perimeter annual average dose in 2000 was 0.644 mSv. The measured dose at the off-site locations near Site 300 was 0.559 mSv. Historically, the off-site dose near Site 300, though

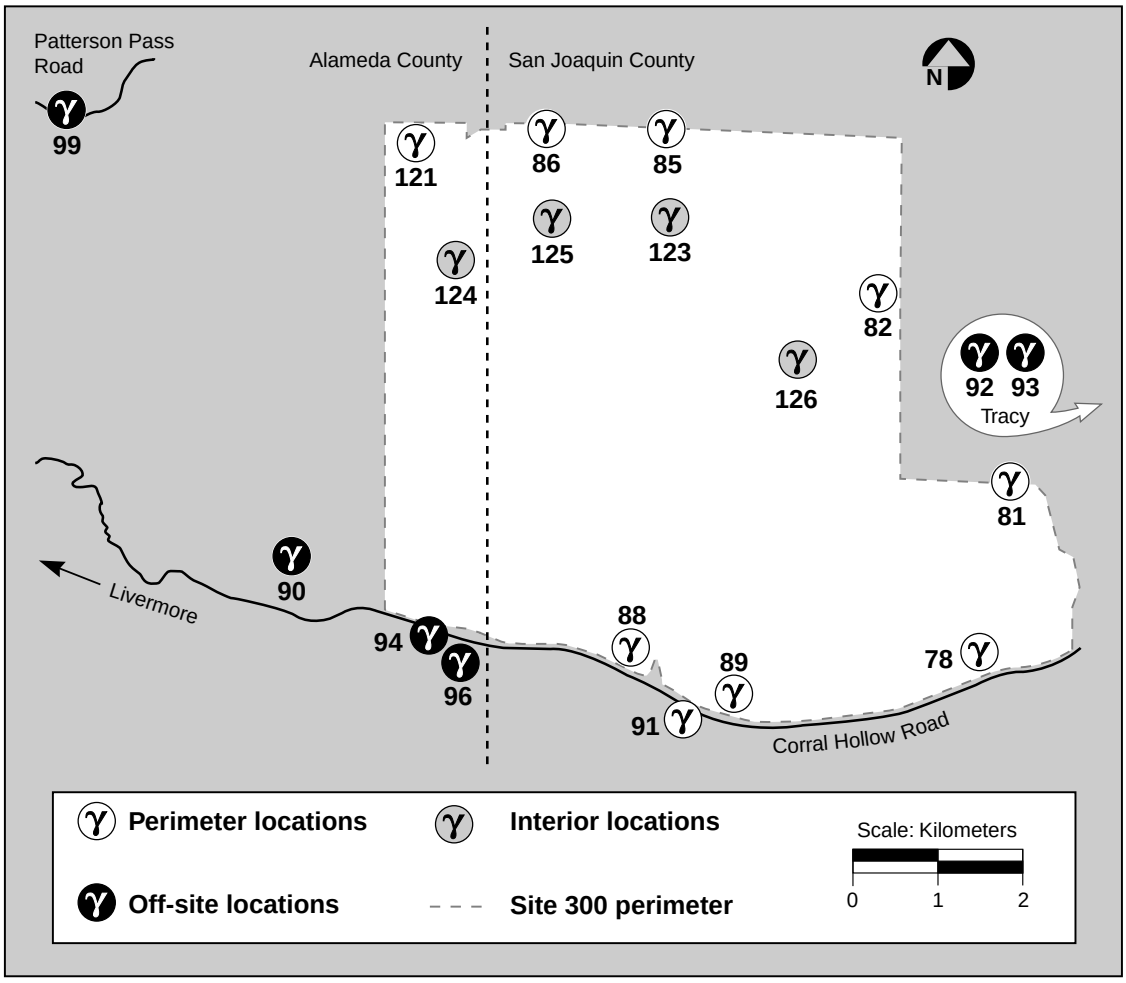


Figure 12-3. Gamma dosimeter locations, Site 300 and vicinity, 2000.

slightly higher, is statistically equivalent to the on-site measured dose. The annual off-site dose reported this year is represented by only three quarters due to the lost samples in the second quarter. The on-site dose is represented by the sum of four quarterly doses measured and therefore yields a higher annual dose this year. The annual dose measured for Tracy was 0.590 mSv and is similar to the annual dose for 1999. All doses are within the predicted range for background radiation, and no LLNL operational impacts are discernible.

The region around Site 300 has higher levels of naturally occurring uranium present in the local geological area called the Neroly Formation. Although this year's annual dose for off-site 300 location was reduced by missing samples, 4 interior locations were added for safety concerns as a result of the fire in the second quarter and will likely impact the data set in the year 2001 by comparison.

The off-site locations have historically represented the high end of background radiation due to the geological substrate mentioned above. Samples collected for the Tracy area, with a measured

Table 12-1. Summary of dose calculations for gamma-monitoring locations (mSv)[a] at all LLNL sites, 2000

Quarter	Location				
	Livermore site	Livermore Valley	Site 300[b]	Tracy	Near Site 300[b]
	Mean 2 SE[c]	Mean 2 SE[c]	Mean 2 SE[c]	Mean 2 SE[c]	Mean 2 SE[c]
First	0.145 ± 0.006	0.144 ± 0.007	0.172 ± 0.006	0.156 ± 0.001	0.186 ± 0.032
Second	0.141 ± 0.007	0.137 ± 0.007	0.159 ± 0.014	0.138 ± 0.010	—[d] ± —[e]
Third	0.140 ± 0.006	0.140 ± 0.007	0.154 ± 0.010	0.142 ± 0.014	0.189 ± 0.030
Fourth	0.145 ± 0.006	0.144 ± 0.006	0.159 ± 0.012	0.154 ± 0.023	0.184 ± 0.037
Annual dose	0.571 ± 0.002	0.565 ± 0.003	0.644 ± 0.007	0.590 ± 0.013	0.559 ± 0.002

a 1 mSv = 100 mrem

b Six of nine Site 300 perimeter samples and three of four near Site 300 samples were lost due to fire.

c SE = Standard Error (standard deviation of the mean)

d Insufficient number of samples to calculate the mean

e Insufficient number of samples to calculate the SE

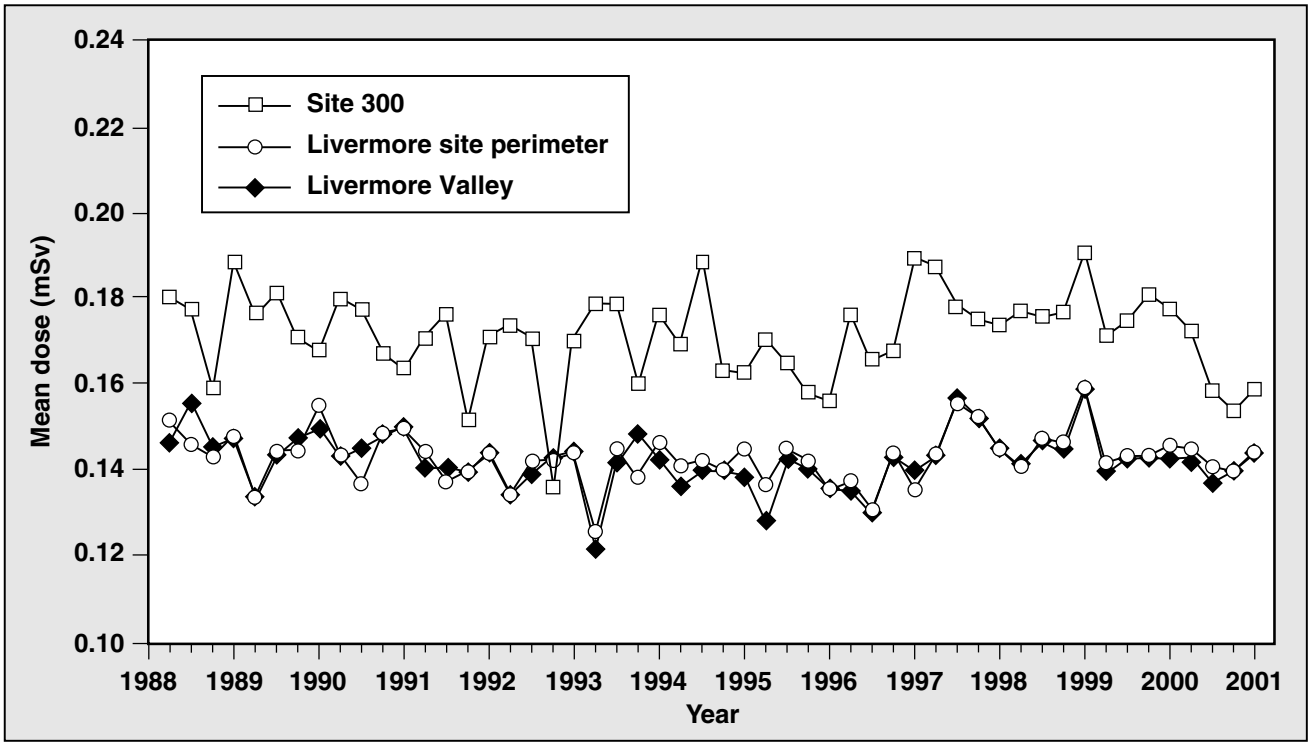


Figure 12-4. Quarterly gamma dose measurements at the Livermore site perimeter, Livermore Valley, and Site 300, 1988–2000

annual dose of 0.590 mSv were not affected by the 2nd quarter loss. This area is underlain by a geological substrate composed of alluvial deposits of clays, sands, and silts overlying bedrock. The difference in the doses can be directly attributed to the difference in geologic substrates.

Table 12-2. Annual dose by year at the Livermore site perimeter caused by direct gamma radiation. [a]

Year	mSv	mrem
1988	0.59	59
1989	0.58	58
1990	0.58	58
1991	0.56	56
1992	0.56	56
1993	0.57	57
1994	0.56	56
1995	0.56	56
1996	0.55	55
1997	0.59	59
1998	0.60	60
1999	0.58	58
2000	0.57	57

a Data normalized to standard 90 days per quarter (360 days per year).

The doses at the Livermore-site perimeter and in the Livermore Valley are comparable from 1988 to 2000. However, while Site 300 doses are similarly comparable, TLDs there continue to record slightly higher direct gamma doses than do the Livermore site and the Livermore Valley, which is expected, given the differences in geology among these sites.

Environmental Impact

Although the contribution of cosmic radiation may vary due to the sun cycle, the sum of the measured terrestrial and cosmic radiation dose has been observed to range from 0.6 to 0.7 mSv/y. In addition, variability due to the local geology and meteorology will also affect this range slightly. Direct radiation doses measured at the Livermore site perimeter in 2000 are near these predicted values and are statistically equivalent to the Livermore Valley doses, which are considered natural background levels. Although measured gamma exposure at Site 300 and the local vicinity are slightly higher than reported for the Livermore site and Livermore Valley, their range is attributed primarily to the variation of the geological substrate containing radionuclides of natural origin. The annual gamma radiation measured by the TLD network indicates that the exposure level is not elevated above natural background for any of the monitoring sites due to LLNL operations.